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Applied Meteorology Unit (AMU) Quarterly Report

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Executive Summary

This report summarizes the Applied Meteorology Unit (AMU) activities for the first quarter of Fiscal Year 2008 (October - December 2008). A detailed project schedule is included in the Appendix.

Task	Peak Wind Tool for User Launch Commit Criteria (LCC)
Goal	Update the Phase I cool season climatologies and distributions of 5-minute average and peak wind speeds. The peak winds are an important forecast element for the Expendable Launch Vehicle and Space Shuttle programs. The 45th Weather Squadron (45 WS) and the Spaceflight Meteorology Group (SMG) indicate that peak winds are a challenging parameter to forecast. The Phase I climatologies and distributions helped alleviate this forecast difficulty. Updating the statistics with more data and new time stratifications will make them more robust and useful to operations.
Milestones	Modified Phase I scripts to process new data, created climatologies and empirical probabilities for the shuttle launch pad wind towers. Wrote scripts to process the data for the prognostic probabilities.
Discussion	Part of this task is to replicate the climatologies and probabilities calculated in Phase I with more data collected since Phase I was completed. The climatologies assist the forecaster and launch team in determining the average conditions for each month at the tower of interest. The probabilities are used to determine the probability of exceeding a certain peak speed given a mean speed value. Continuing work includes developing Gumbel distributions for the probabilities and probabilities of exceeding a peak value 2, 4, 8, and 12 hours after a mean speed observation.
Task	Peak Wind Tool for General Forecasting
Goal	Develop a tool to forecast the peak wind speed for the day from the surface to 300 ft on Kennedy Space Center (KSC) / Cape Canaveral Air Force Station (CCAFS) during the cool season months October – April. The tool should be able to forecast the timing of the peak wind speed and the background average wind speed, based on observational data available for the 45 WS 0700L weather briefing.
Milestones	Completed development of the tool, which is run as an Excel graphical user interface (GUI) application. Began testing the tool and continued writing the final report.
Discussion	Based on feedback from the 45 WS, the tool was modified by adding equations to predict the probabilities that the daily peak wind will meet or exceed 35, 50, and 60 kts.

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Executive Summary, *continued*

Task	<u>Situational Lightning Climatologies for Central Florida, Phase III</u>
Goal	Customize the Advanced Weather Interactive Processing System (AWIPS) to allow display of the composite soundings created in Phase II. This will give forecasters at the National Weather Service in Melbourne, FL (NWS MLB) the capability to compare the current state of the atmosphere with climatology. After comparing current soundings to composite soundings, forecasters can make appropriate adjustments to their lightning forecast for the day.
Milestones	No work was done on the task during the quarter.
Discussion	Work was delayed on this task with customer permission due to higher priority work on the Volume Averaged Height Integrated Radar Reflectivity (VAHIRR) task. Work on this task will resume in February.

Task	<u>Volume Averaged Height Integrated Radar Reflectivity (VAHIRR)</u>
Goal	Transition the VAHIRR algorithm into operations using Weather Surveillance Radar 1988 Doppler (WSR-88D) data. The previous lightning LCC (LLCC) for anvil clouds to avoid triggered lightning were restrictive and lead to unnecessary launch delays and scrubs. The VAHIRR algorithm was developed as a result of the Airborne Field Mill program (ABFM) as part of a new LLCC for anvil clouds. This algorithm will assist forecasters in providing fewer missed launch opportunities with no loss of safety compared with the previous LLCC.
Milestones	Completed an analysis of the differences between the AMU and ABFM VAHIRR radar products.
Discussion	The four possible contributors to the differences between the two VAHIRR products were analyzed. The likely primary contributor was differences in vertical grid spacing. Because the AMU VAHIRR product failed the initial test, it will not be released for operational use. A final report will be written to describe the development and testing of the AMU VAHIRR product.

Distribution (continued from Page 1)

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Task — Impact of Local Sensors

Goal Determine the impact to high resolution model forecasts due to denial of local observations. Impending budget cuts may result in the elimination of some weather observation systems on KSC/CCAFS. Loss of these data may affect output from local weather prediction models. Forecasters at the 45 WS and SMG use such model output for their operational forecasts. To determine the effects of losing these data sources, the model will be run using four different data ingest configurations, including and excluding the data. The results will help determine the importance of the instruments that may be eliminated.

Milestones Began identifying candidate cool season days for November 2007 and archived the data. Re-ran the Local Analysis and Prediction System (LAPS) analyses after two separate errors were found in the model output. Currently re-running the Weather Research and Forecasting (WRF) model for all warm season days. Began analysis of warm season days.

Discussion Three candidate days were identified for the month of November 2007. A previous version of LAPS was used to re-run all warm season LAPS analyses after an error was found in the current version in which the rainwater and graupel mixing ratio values were set to 0. Another error was identified in the default pressure levels of LAPS that caused a warm bias in the 0-hour surface temperature field. The LAPS-WRF model is now being re-run after addressing these issues. Analysis of the model output for the warm season days commenced after the LAPS errors were corrected and model re-run.

Task — Radar Scan Strategies for the PAFB WSR-74C Replacement

Goal Develop a scan strategy for the new radar that will replace the 45 WS Weather Surveillance Radar Model 74C (WSR-74C). Data from the new radar will be used by forecasters at the 45 WS, SMG, and NWS MLB to issue weather warnings and watches. The new radar will also aid in detecting cloud electrification to improve the timeliness of lightning advisories, and maintain the capability to evaluate LLCC.

Milestones After discussions with the 45 WS, made adjustments to the angles initially suggested by them in order to improve evaluation of radar-related LLCC during the warm and cool seasons with a single scan strategy.

Discussion The adjusted scan strategy provides high resolution coverage over the KSC/CCAFS launch complexes in the altitude range from about 7,000 to 27,000 ft. This design addresses requirements for high vertical resolution data over the launch complexes for improved evaluation of LLCC. Another potential scan strategy was developed by revising the current WSR-74C scan strategy to include one additional elevation angle, and by decreasing the lowest elevation angle to 0.2 degrees. Vertical gaps over the launch complexes in the revised WSR-74C design are about 60% larger than those in the adjusted 45 WS design. The advantage of this design is that it produces a raw data sample that is more spatially uniform over the radar surveillance area.

Special Notice to Readers

Applied Meteorology Unit (AMU) Quarterly Reports are now available on the Wide World Web (www) at http://science.ksc.nasa.gov/amu/.

The AMU Quarterly Reports are also available in electronic format via email. If you would like to be added to the email distribution list, please contact Ms. Winifred Lambert (321-853-8130, lambert.winifred@ensco.com). If your mailing information changes or if you would like to be removed from the distribution list, please notify Ms. Lambert or Dr. Francis Merceret (321-867-0818, Francis.J.Merceret@nasa.gov).

Background

The AMU has been in operation since September 1991. Tasking is determined annually with reviews at least semi-annually. The progress being made in each task is discussed in this report with the primary AMU point of contact reflected on each task.

AMU ACCOMPLISHMENTS DURING THE PAST QUARTER

SHORT-TERM FORECAST IMPROVEMENT

Peak Wind Tool for User LCC (Ms. Lambert and Dr. Short)

The peak winds are an important forecast element for the Expendable Launch Vehicle (ELV) and Space Shuttle programs. As defined in the Launch Commit Criteria (LCC) and Shuttle Flight Rules (FR), each vehicle has peak wind thresholds that cannot be exceeded in order to ensure safe launch and landing operations. The 45th Weather Squadron (45 WS) and the Spaceflight Meteorology Group (SMG) indicate that peak winds are a challenging parameter to forecast, particularly in the cool season. To alleviate some of the difficulty in making this forecast, the AMU calculated cool season climatologies and distributions of 5-minute average and peak winds in Phase I (Lambert 2002). The 45 WS requested that the AMU update these statistics with more data collected over the last five years, using new time-period stratifications, and test another parametric distribution. These modifications will likely make the statistics more robust and useful to operations. They also requested a graphical user interface (GUI) similar to that from Phase II (Lambert 2003) that will display the mean and peak speed climatologies and probabilities of meeting or exceeding certain peak speeds based on the average speed.

Climatology Calculations

Ms. Lambert modified scripts from the Phase I task to calculate the same climatologies for the new period of record. Those climatologies include

- Hourly means and standard deviations (σ) of the 5-minute mean and peak speeds,
- Directional means and σ of the 5-minute mean and peak speeds in 10-degree increments, and
- Hourly means and σ of the 5-minute mean and peak speeds further stratified by direction in 45-degree increments.

These products show the historical mean behavior and variability of the wind speeds for different times of the day and from different directions.

After running the scripts for the shuttle launch pad towers 0393, 0394, 0397, and 0398, Ms. Lambert imported the data into Excel and created PivotCharts as in Phase I. Figure 1 shows the hourly peak and mean speed climatological values for February at Tower 0393. This product will show users the preferred times of day for higher 5-minute mean and peak wind speeds.

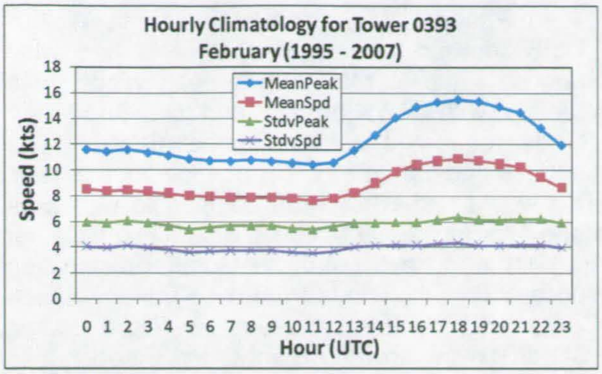

Figure 1. The hourly climatology for February at Tower 0393. The legend shows the curve colors for the average 5-minute peak (MeanPeak) and mean speeds (MeanSpd), and σ of the peak (StdvPeak) and mean speeds (StdvSpd).

Figure 2 shows the directional mean and peak speed climatological values in 10° bins. This climatology can show users preferred directions of higher wind speeds for each month. Similarly, the number of observations in Figure 3 used to calculate the values in Figure 2 can be used to determine a climatologically preferred wind direction for each month.

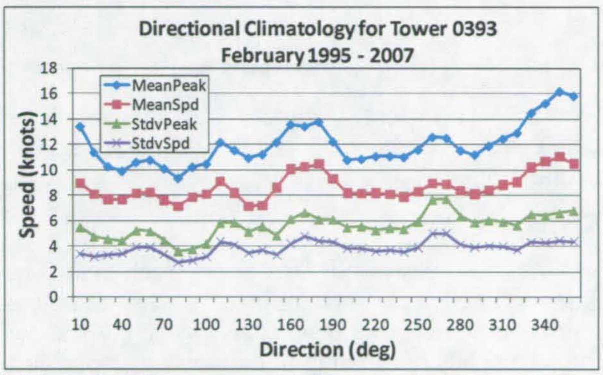

Figure 2. The same variables as in Figure 1, but for the directional climatology in 10° bins.

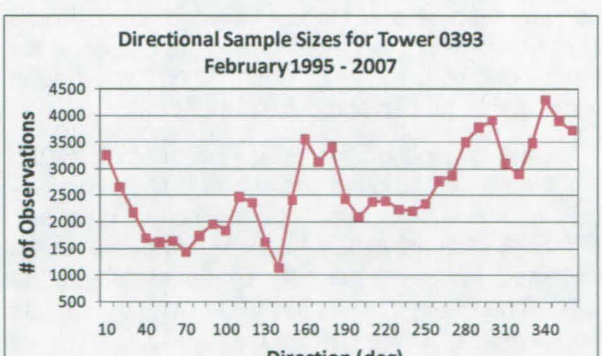

Figure 3. The number of observations in each 10° direction bin used to create the values in Figure 2.

Figure 4 shows hourly climatology for the wind speeds from the 315-360° direction bin, or the north-northwest. The highest peak speeds in the directional climatology (Figure 2) were in this direction range. The highest peak speeds for the hourly (Figure 1) and directional (Figure 2) climatologies was close to 16 kts at 1800 UTC (1:00 PM EST) and 350°, respectively. When stratifying by both hour and direction, the highest peak speed in Figure 4 is higher at 19 kts at 1900 UTC (2:00 PM EST). This product would show more precise climatological values for times and directions of interest than the separate hourly and directional climatologies. However, the values in Figures 1 and 2 can be used to help the user focus on a particular hour/direction bin. The values in Figure 5 are similar to those in Figure 3 except these values show a preferred time of occurrence from a particular direction

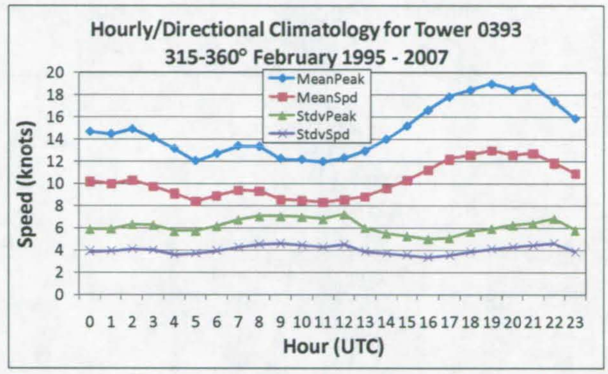

Figure 4. The same variables as in Figure 1, but for the hourly/directional climatology in the 315-360°, or north-northwest, bin.

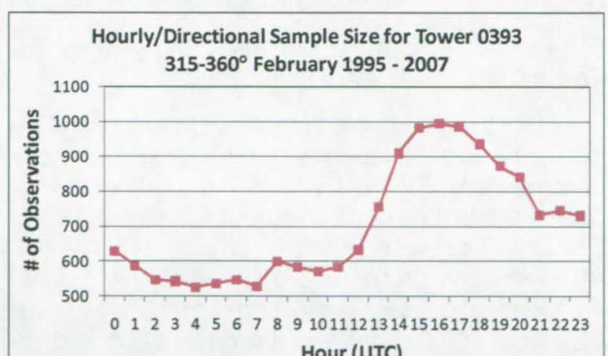

Figure 5. The number of observations in the 315-360° direction bin for each hour used to create the values in Figure 4.

Probability Calculations

The probabilities of exceeding specified peak speeds will be calculated empirically and with a parametric distribution, as in Phase I. Ms. Lambert modified the Phase I script that calculated the

empirical probabilities to process the new data set and began modifying the script that calculated the parametric probabilities.

As with the climatologies, Ms. Lambert tested the empirical script using data from the shuttle launch pad towers. The script calculates a complementary cumulative distribution function (CDF), which is 1 – CDF. This is done so that the probability of exceeding a peak speed is displayed as opposed to the probability of not exceeding a peak speed in a regular CDF. Figure 6 shows the complementary CDFs (hereafter CDFs for ease of reference) for Tower 0393 in February. Each curve represents a mean speed as defined in the legend. Only the even speeds from 6 – 30 kts are shown to keep the chart uncluttered and easy to interpret. The points along each curve are at the intersection of a probability on the vertical axis and a peak speed on the horizontal axis. This is the probability of exceeding that peak speed given the mean speed represented by the curve.

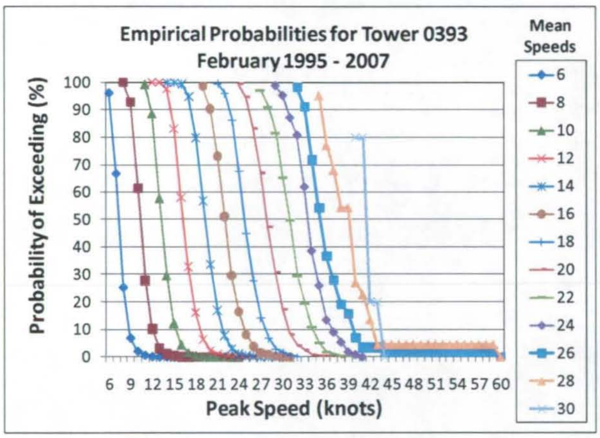

Figure 6. The complementary CDF curves for Tower 0393 in February.

Note that the curves for mean speeds > 20 kts in Figure 6 are not as smooth as those of the lower speeds. Figure 7 shows the total number of observations in each distribution displayed in Figure 6. The value falls from 957 at 18 kts to 393 at 20 kts and drops to 5 at 30 kts. The smaller sample sizes result in an under-sampling of the individual peak speeds in the distribution and an irregular curve.

Smoothing over the irregularities in the CDFs due to under-sampling is one reason this task will involve fitting a parametric distribution to the data (Wilks 2006). Another is to estimate probabilities of peak gusts associated with average wind speeds outside the range of the observations in the data sample.

In Phase I, Ms. Lambert used the Weibull distribution for this purpose since it had wide support in the literature to fit peak winds. In a meeting with Ms. Lambert and Dr. Short, Mr. Roeder requested that the Gumbel distribution be used as the parametric distribution in the task. This would make this work compatible with work done by scientists at Marshall Space Flight Center (MSFC) who have used the Gumbel distribution successfully with winds from the Kennedy Space Center (KSC)/Cape Canaveral Air Force Station (CCAFS) wind tower network. Mr. Roeder also indicated that there would be no need to compare the Gumbel and Weibull distributions unless there is sufficient time left in the task.

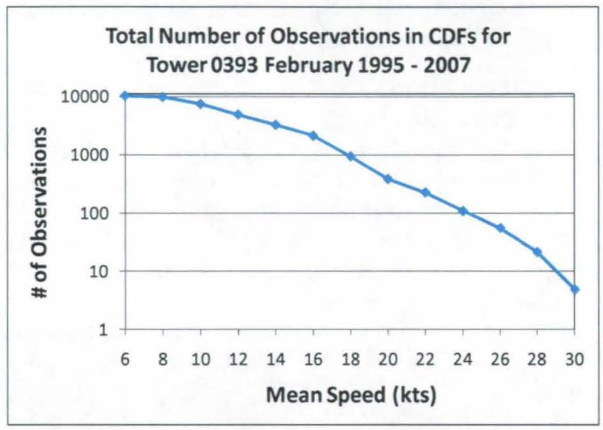

Figure 7. The total number of observations displayed logarithmically for each mean speed distribution in Figure 6.

Continuing Work

Ms. Lambert and Dr. Short met with Mr. Roeder to discuss development of the empirical and parametric prognostic CDFs, which will show the probability of meeting or exceeding a specified peak speed within 2, 4, 8, and 12 hours after a mean speed observation. Based on that conversation, Ms. Lambert created an S-PLUS script to collect the data for the 2-hour period for each hour of the day in each month and began running it to gather and organize the data

Data collection for the prognostic CDFs involves a re-sampling technique that uses all 5-minute mean and peak speeds in the data set. Figure 8 demonstrates how the data are being collected for the 2-hour time interval after 0000 UTC. The mean speeds in the 30 minute intervals before and after the central time of 0000 UTC will represent the mean speed CDFs. This time period is 2330–0025 UTC in Figure 8 and is highlighted in blue. The brackets above the timeline encompass the range of times from which the

peaks are drawn for the first and last times in the blue area. The peak speeds associated with the mean at 2330 UTC will begin at 2335 and end at 0125 UTC, and the peaks associated with the mean at 0025 UTC will begin at 0030 and end at 0220 UTC. The same procedure will be followed for every time between 2330 to 0025 UTC for every 0000 UTC in each month.

Each set of 23 peak values will be binned with its associated mean speed at the beginning of the 2-hour (4-, 8-, 12-hour) period. Each mean speed will then have a distribution of peak speeds associated with it. These distributions will be used to calculate empirical and parametric CDFs.

Conference Presentation

Ms. Lambert wrote a manuscript describing this work for the 19th Conference on Probability and Statistics, part of the 88th American Meteorological Society (AMS) Annual Meeting in January 2008.

Contact Ms Lambert at 321-853-8130 or lambert.winnie@ensco.com, or Dr. Short at short.dave@ensco.com or 321-853-8105 for more information.

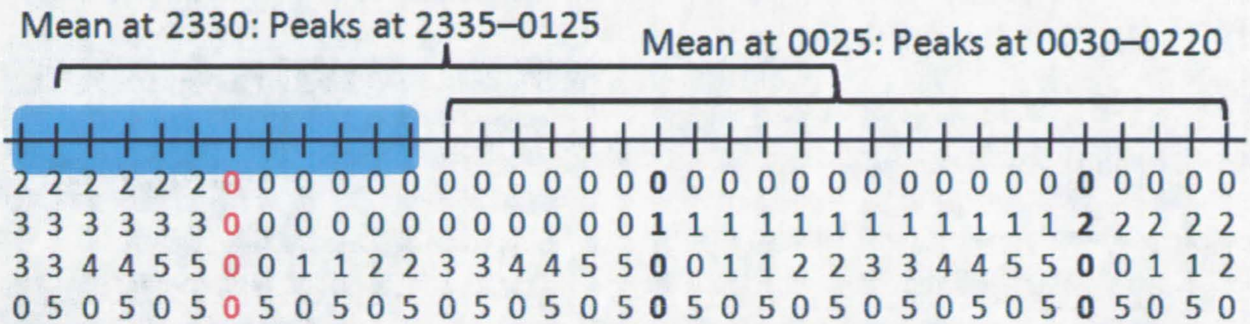

Figure 8. Timeline demonstrating how the data for the 2-hour probabilities at 0000 UTC are collected. The times highlighted in blue are those from which the 5-minute means are collected. The brackets above the timeline represent the range of times over which the 5-minute peaks are collected for the first and last mean speed observations in the blue shaded area. The time of interest, 0000 UTC, is highlighted in red.

Peak Wind Tool for General Forecasting (Mr. Barrett and Dr. Short)

The expected peak wind speed for the day is an important element in the daily morning forecast for ground and space launch operations at KSC and CCAFS. The 45 WS must issue forecast advisories for KSC/CCAFS when they expect peak gusts to exceed 35 kt, 50 kt, and 60 kt thresholds at any level from the surface to 300 ft. However, the 45 WS forecasters indicate that peak wind speeds are a challenging parameter to forecast, regardless of their value. They requested that the AMU develop a tool to help them forecast the daily average and highest peak non-convective wind speed, and the timing of the peak speed, from the surface to 300 ft on KSC/CCAFS for the cool season (October-April). The AMU used a 4-year database of high resolution soundings and other observational data available by the morning weather briefing at 0700 local time to develop a tool that provides a forecast of the peak wind speed for the day, its timing, and the average wind speed at the time of the peak.

Warning/Advisory Thresholds

Based on feedback from the 45 WS, Mr. Barrett added equations to forecast the probabilities that the daily peak wind speed will meet or exceed the 45 WS wind warning/advisory thresholds of 35, 50, and 60 kts. The probabilities were based on the estimated error of the linear regression equations for the peak wind speed using the following equation (derived from Wilks 2006, Equations 4.29 and 6.22):

$$1-\left[0.5*\left(1\pm\sqrt{1-e^{\left(-2/\pi*((x-y)/z)^2\right)}}\right)\right],$$

where x is the threshold value (35, 50, or 60), y is the predicted peak wind speed, and z is the predicted sigma (estimated error of the linear regression equation). The + sign before the radical is used for $y < x$, and the – sign used for $y > x$. For each threshold, a probability value was calculated from each of the three regression equations (AMU Quarterly Report Q3 FY07) and averaged, weighted by each equation's mean absolute error.

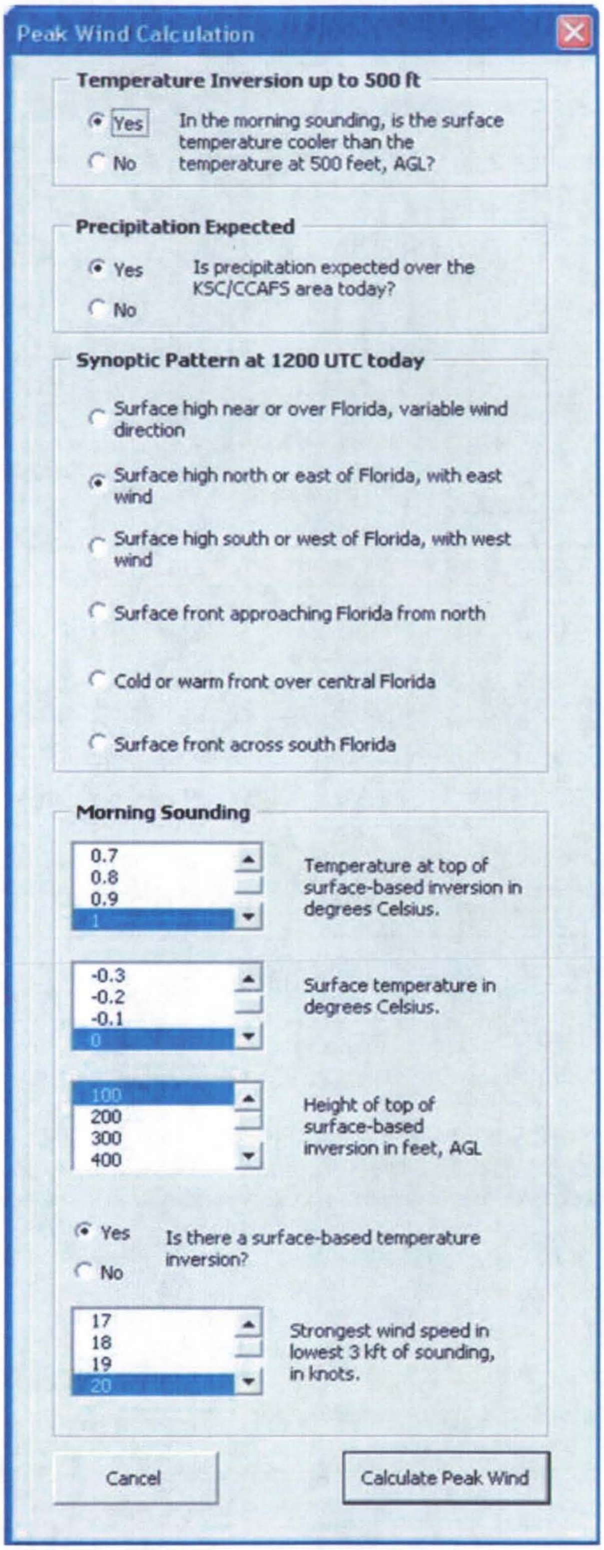

Figure 9. Peak wind tool input GUI.

Forecast Tool

Mr. Barrett began testing the final version of the tool. In order to run the tool, the user first opens the Microsoft Excel file. The user navigates to the introductory worksheet and clicks the "Start Peak Wind Calculation" button. The input GUI is then displayed (Figure 9, left). The forecaster inputs values based on the observed upper-air sounding, synoptic weather pattern, and precipitation forecast. After the forecaster finishes entering data, the output GUI (Figure 10) displays the forecast speed and timing of the peak wind, average wind speed, and probabilities of meeting or exceeding the 45 WS warning/advisory thresholds.

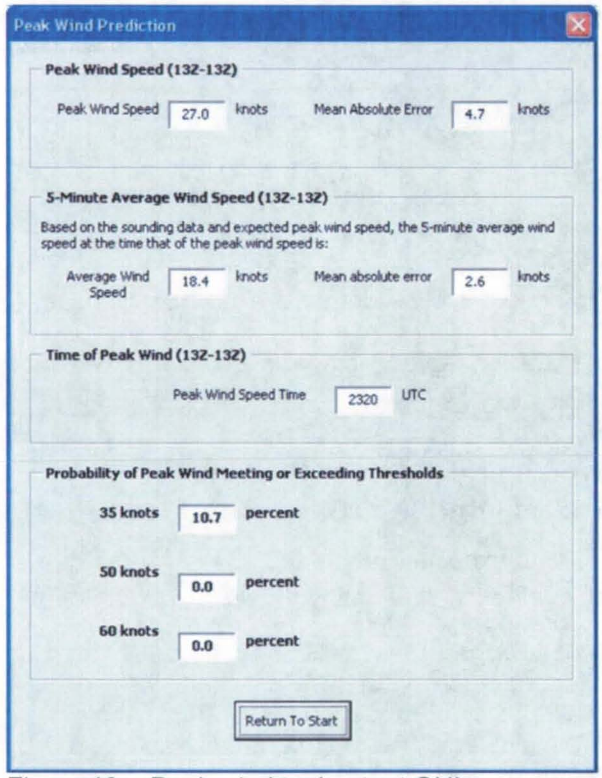

Figure 10. Peak wind tool output GUI.

Final Report

Mr. Barrett continued writing the final report. He will have a first draft ready for internal review in January.

Contact Mr. Barrett at 321-853-8205 or barrett.joe@ensco.com, for more information.

Situational Lightning Climatologies for Central Florida, Phase III (Mr. Barrett)

The threat of lightning is a daily concern during the warm season in Florida. Recent research has revealed distinct spatial and temporal distributions of lightning occurrence that are strongly influenced by large-scale atmospheric flow regimes in Florida. The first two phases of this work involved developing spatial and temporal climatologies of lightning occurrence based on the flow regime. In the first part of Phase II, Dr. Short created climatological, or composite, soundings of wind speed and direction, temperature, and dew point temperature at Jacksonville (JAX), Tampa (TBW), Miami (MFL), and CCAFS (XMR), Florida for each of eight flow regimes, resulting in 32 soundings (Short 2006). These soundings could only be displayed using the National version of the Skew-T Hodograph analysis and Research Program (NSHARP). For Phase III, the National Weather Service in Melbourne, FL (NWS MLB) requested that the AMU make these composite soundings available for display in the Advanced Weather Interactive Processing System (AWIPS) so that they can be overlaid onto current soundings. This will allow the forecasters to compare the current state of the atmosphere with climatology. After comparing current soundings to composite soundings, the NWS MLB forecasters can make adjustments to the forecast of lightning in their Hazardous Weather Outlook and lightning threat index products.

No work was done on this task during the quarter due to higher priority work on the VAHIRR task. The work schedule was reprogrammed with customer permission. Mr. Barrett will resume work on this task in February. Contact Mr. Barrett at 321-853-8205 or barrett.joe@ensco.com for more information.

INSTRUMENTATION AND MEASUREMENT

Volume Averaged Height Integrated Radar Reflectivity (VAHIRR) Algorithm (Mr. Barrett, Ms. Miller, Ms. Charnasky, Dr. Merceret, and Mr. Gillen)

Lightning LCC (LLCC) are used for all launches, whether Government or commercial, using a Government or civilian range (Willett et al. 1999). Shuttle lightning FR are also used for all landings. These rules are designed to avoid natural and triggered lightning strikes to space vehicles, which can endanger the vehicle, payload, and general public. The current LLCC for anvil clouds, meant to avoid triggered lightning, have been shown to be overly restrictive. They ensure safety, but falsely warn of danger and lead to costly launch delays and scrubs. A new LLCC for anvil clouds, and an associated radar algorithm needed to evaluate that new LLCC, were developed using data collected by the Airborne Field Mill (ABFM) research program managed by KSC (Dye et al. 2006, 2007). Dr. Harry Koons of Aerospace Corporation conducted a risk analysis of the VAHIRR algorithm. The results indicated that the LLCC based on the VAHIRR algorithm would pose a negligible risk of flying through hazardous electric fields.

Mr. Barrett performed a comparison test between the AMU VAHIRR product and the ABFM VAHIRR product (AMU Quarterly Report Q4 FY07) and found significant differences. The AMU VAHIRR values had a large positive bias of 33%. A plot of the two products shows a large spread across the linear regression line, indicating a poor linear relationship (Figure 11). Mr. Barrett then analyzed the two components of VAHIRR: volume average reflectivity and average cloud thickness. The AMU product had a positive bias of 8% in volume average reflectivity and a positive bias of 23% in average cloud thickness. A good linear relationship was seen in the volume average reflectivity (Figure 12) between the two products, while a poor linear relationship was seen in average cloud thickness (Figure 13).

Mr. Barrett and Dr. Merceret considered four possible contributors to the differences between the AMU and ABFM VAHIRR products:

- Errors in the latitude/longitude positions of the ABFM aircraft or ABFM and AMU VAHIRR values,
- Errors in calculating cloud heights,
- The ABFM VAHIRR product uses radar reflectivities at all vertical levels to calculate the cloud top and base, while the AMU VAHIRR product only uses reflectivities at or above the freezing level, and
- Differences in vertical grid spacing in the two products.

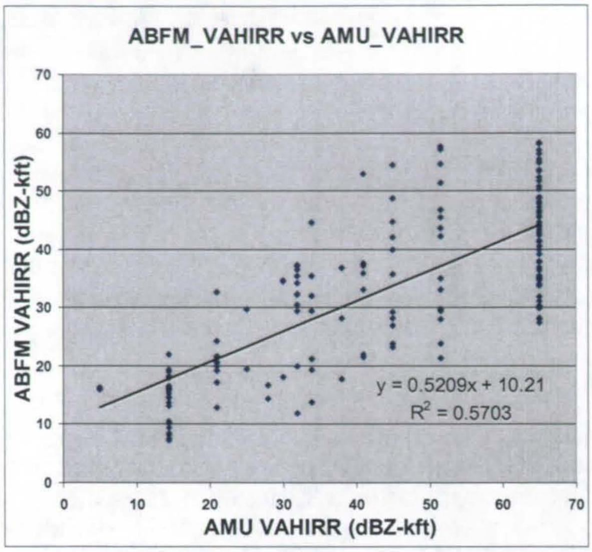

Figure 11. Scatter plot of ABFM (y-axis) and AMU VAHIRR values (x-axis). The linear regression equation and coefficient of determination (R^2) are displayed in the lower right. The linear regression line is displayed in black.

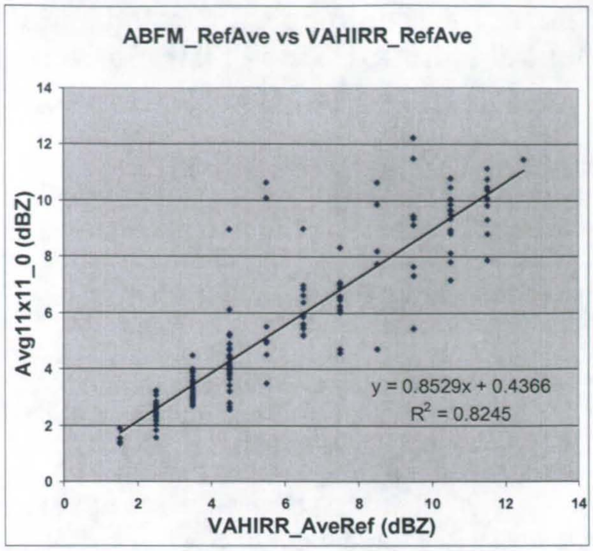

Figure 12. Scatter plot of the ABFM (y-axis) and AMU (x-axis) volume average reflectivity. The linear regression equation and coefficient of determination (R^2) are displayed in the lower right. The linear regression line is displayed in black.

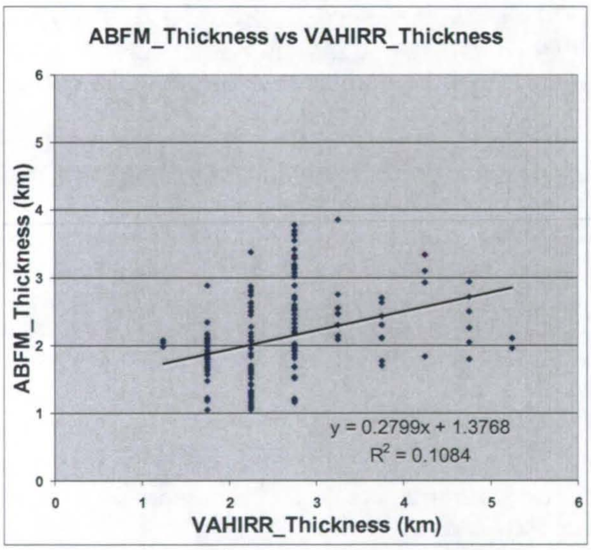

Figure 13. Scatter plot of average cloud thickness in the ABFM (y-axis) and AMU products (x-axis). The linear regression equation and coefficient of determination (R^2) are displayed in the lower right. The linear regression line is displayed in black.

Mr. Barrett compared the latitude and longitude coordinates of the VAHIRR values in the two products and concluded that the differences in position were generally 3 km or less. Therefore, it appears that the first possible contributor is not significant. Mr. Barrett reviewed the software source code for both products and did not find significant errors in calculating cloud heights, indicating that the second possible contributor is insignificant, also.

The methodologies for how the two products calculate cloud top and base, the third possible contributor, were discussed in detail in the previous quarterly report (AMU Quarterly Report Q4 FY07). The difference in methodology gives a positive bias for cloud top and base in the AMU product. Since cloud thickness is the difference in altitude of cloud top and base, this likely does not have a significant effect on the average cloud thickness or VAHIRR values.

Mr. Barrett and Dr. Merceret investigated the fourth possible contributor, differences in vertical grid spacing. They performed two tests to determine whether the differences are due to errors by the ABFM product or AMU product:

- For clouds having a limited range of thickness, they calculated the ratios of cloud thickness, average reflectivity, and VAHIRR as a function of distance from the radar, and
- For clouds within a roughly fixed distance from the radar, where the vertical beam spacing is significantly greater than 1 km, they calculated the same ratio quantities as the first test but as a function of cloud thickness.

They expected the ratios of cloud thickness and VAHIRR to increase with distance from the radar, and that the same ratios would decrease with increasing cloud thickness. However, the results of the two tests were inconclusive, due to the weak linear relationships found in the ratios versus distance and cloud thickness.

The significant difference in values between the ABFM and AMU values caused Mr. Barrett and Dr. Merceret to conclude that the AMU VAHIIRR product failed the test. Because of this, they will not release the AMU VAHIRR product for operational use. Mr. Barrett will write a final report describing the development and testing of the AMU VAHIRR product.

For more information, contact Ms. Miller at 321-783-9735 ext. 221 or miller.juli@ensco.com; Mr. Barrett at barrett.joe@ensco.com or 321-853-8205, or Dr. Merceret at 321-867-0818 or Francis.J.Merceret@nasa.gov.

Impact of Local Sensors (Dr. Watson and Dr. Bauman)

Forecasters at the 45 WS use observations from the KSC/CCAFS wind tower network and daily rawinsonde observations (RAOB) to issue and verify wind advisories, watches, and warnings for operations. They are also used by SMG to support Shuttle landings at the KSC Shuttle Landing Facility (SLF). Due to impending budget cuts, some or all of the mainland wind towers (Figure 14) and RAOBs may be eliminated. The loss of these data may significantly impact the forecast capability of the 45 WS and SMG. The AMU was tasked to conduct an objective independent modeling study to determine how important these observations are to the accuracy of the model output used by the forecasters as input to their forecasts. To accomplish this, the AMU will perform a sensitivity study using the Weather Research and Forecasting (WRF) model run with and without KSC/CCAFS wind tower XMR RAOB observations. The AMU will assess the accuracy of model forecasts by comparing operationally significant model output parameters with advisory and warning criteria forecast by the 45 WS. The model forecasts will be displayed graphically with the observations overlaid for comparison to determine the model performance when initialized with and without wind tower and RAOB observations. These analyses will help the 45 WS determine the importance of the instruments slated for elimination.

Determining Cold Season Candidate Days

The period of record for choosing cool season candidate days is November 2007 through January 2008. Dr. Watson began identifying potential cool season days in November and archiving the data. The criteria for selection included the issuance of a wind advisory or warning for the KSC/CCAFS area by 45 WS the as well as the existence of specific cold season phenomena, such as fronts and their associated precipitation. She examined daily weather maps to determine days in which there was a front or low pressure system over Florida or in the immediate area. In the end, three days in November met these criteria.

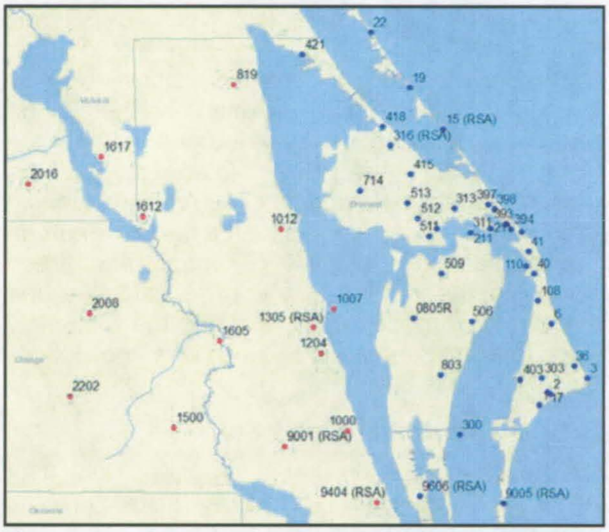

Figure 14. Map of the KSC/CCAFS area showing mainland tower locations (red dots) and island/cape tower locations (blue dots).

LAPS/WRF Model Configuration

After Dr. Watson downloaded and began running the most recent version of the Local Analysis and Prediction System (LAPS), she found an error in the output in which values of rainwater and graupel mixing ratio were being set to 0. Dr. Watson determined she might not be able to remedy the problem within a reasonable amount of time and decided to use a previous version of LAPS in which this error did not occur. She continued to run and completed the LAPS analyses and the WRF model runs for the warm season candidate days.

While analyzing WRF model 0-hour output, Dr. Bauman identified a warm bias on the order of 10-15 °F in the surface temperature field. Upon further analysis, he discovered the problem

existed in all the model runs completed. Drs. Bauman and Watson contacted Dr. John McGinley of the Earth System Research Laboratory's (ESRL) Global Systems Division (GSD) to determine the cause of the problem. After consultation with Dr. McGinley, Dr. Watson traced the bias back to the LAPS configuration of having the default bottom pressure level to extend below the terrain and the observations.

The default bottom pressure levels were 1050 and 1100mb, corrected to sea level. Dr. McGinley indicated that when LAPS has multiple levels below the terrain, problems can occur since the software is still applying balance at those fictional levels. Assumptions in the extrapolation of pressure to sea level could cause some parts of the lowest levels to be above ground in the mountainous Colorado region, where LAPS was originally developed and used. This would leave fewer levels below ground. Dr. McGinley suggested that the best solution for the Florida region was to minimize the value and depth of the lowest pressure level. Dr. Watson deleted the 1100 mb pressure level and is currently re-running LAPS-WRF for all candidate days. Dr. Bauman began reanalyzing the WRF output and, upon reviewing the 0-hour temperature fields for the first two new model runs, he found the extremely large warm temperature bias was no longer evident.

Data Analysis and Display Software

Dr. Bauman downloaded and installed Unidata's Integrated Data Viewer (IDV) software to use as the data analysis and display software for this task. The IDV software runs on a Windows-based PC, which is logistically more efficient than running the General Meteorological Package (GEMPAK) or Grid Analysis and Display System (GrADS) software remotely on AMU Linux platforms. It is a Java™-based software framework for analyzing and visualizing geoscience data, including satellite imagery, gridded data, surface observations, balloon soundings, Weather Surveillance Radar 1988-Doppler (WSR-88D) Level II and Level III radar data, and National Profiler Network data. It also has a variety of high resolution map backgrounds with many display options.

Model and Data Analysis

Dr. Bauman compared the 0-hour model temperature and wind speed output from the new runs to the observed mesonet and METAR temperatures and wind speeds to make sure the model was properly initialized. His preliminary analysis of the warm season cases indicated a model surface temperature cool bias of 3-4° F (Figure 15) and an average wind speed high bias of 6-8 kt. However, the biases were consistent among all four variations of model runs with and without the mainland wind towers and XMR RAOB. It does not appear that the inclusion or absence of these data made a difference in the initial conditions.

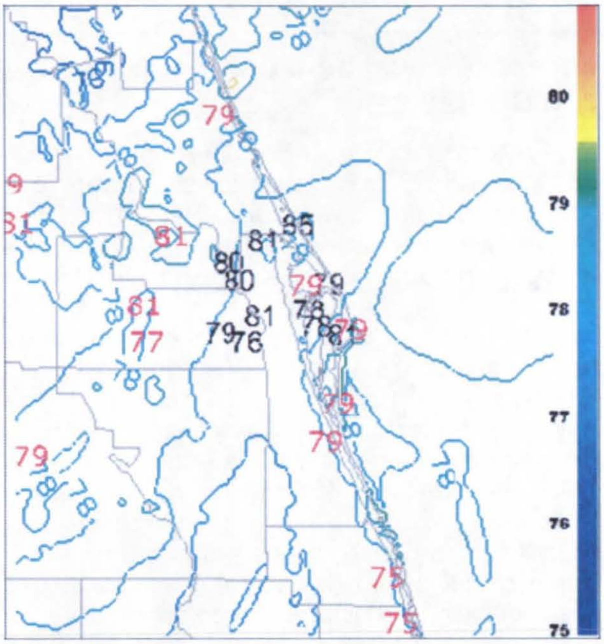

Figure 15. WRF initial conditions showing 2 m height isotherms in °F (color legend at right) and observed 6 ft temperatures in °F from the KSC/CCAFS wind towers (black) and METAR stations (red).

Dr. Bauman then examined the WRF forecasts valid near the time of weather events in the wind tower network based on 45 WS advisories and warnings. The goal was to determine

1) If the model could provide an indicator to the forecaster that there may be weather meeting advisory or warning criteria for the day, and
2) If including or excluding mainland wind towers and/or the XMR RAOB made a difference in the model forecast.

Based on the composite reflectivity model forecasts, WRF was able to provide an indication that convection could reach levels to warrant advisory or warning criteria on some days. However, WRF typically did not correctly forecast location or timing of the convection. One of the

better forecasts of composite reflectivity is shown in Figure 16. The color-filled contours are the 0.5° elevation radar reflectivity values from the NWS MLB WSR-88D for the 1754 UTC volume scan on 19 July 2007 and the contours are the 9-hour forecast of composite reflectivity values valid 1800 UTC 19 July 2007. The model over-forecast the areal coverage of reflectivity but correctly forecast maximum reflectivity values of ~50 dBZ over KSC/CCAFS as shown by the area circled in the figure. This would have provided useful information to the forecaster of the threat for convective activity during the day.

Figure 17 shows the WRF 9-hour forecast of maximum wind speeds at a height of 10 m as color-shaded contours and the observed 54 ft average wind speed and direction (barbs) and peak wind speed (numbers) for the KSC/CCAFS wind towers. The four panels represent the model forecasts with and without the mainland wind towers and XMR RAOB as follows:

a) All mainland wind towers and the XMR RAOB,
b) All mainland wind towers and no XMR RAOB,
c) The XMR RAOB and no mainland wind towers, and
d) No mainland wind towers and no XMR RAOB.

The model did well at forecasting peak wind speeds of 20-25 kt over the southern part of the KSC/CCAFS region associated with the forecast convection. The location of the peak observed wind speed of 28 kt is shown by a black circle in each panel. It is important to note that the inclusion or absence of the mainland towers and XMR RAOB made little difference in the model forecast in this case. Dr. Bauman's preliminary analysis of the other warm season days also indicated the inclusion or absence of the mainland towers and XMR RAOB made little difference in the model forecast.

For more information contact Dr. Watson at watson.leela@ensco.com or 321-853-8264 or Dr. Bauman at bauman.bill@ensco.com or 321-853-8202.

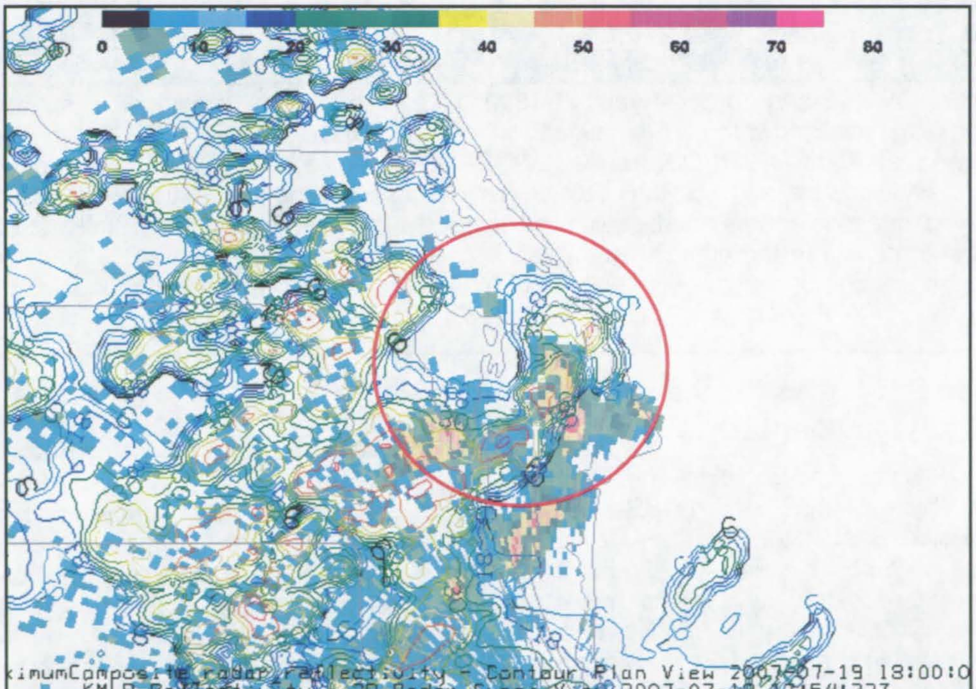

Figure 16. WRF 9-hour forecast valid at 1800 UTC 19 July 2007 of composite reflectivity contours overlaid on 0.5° elevation radar reflectivity (color-filled contours) from the NWS MLB WSR-88D 1754 UTC volume scan. The reflectivity color legend is at the top of the image.

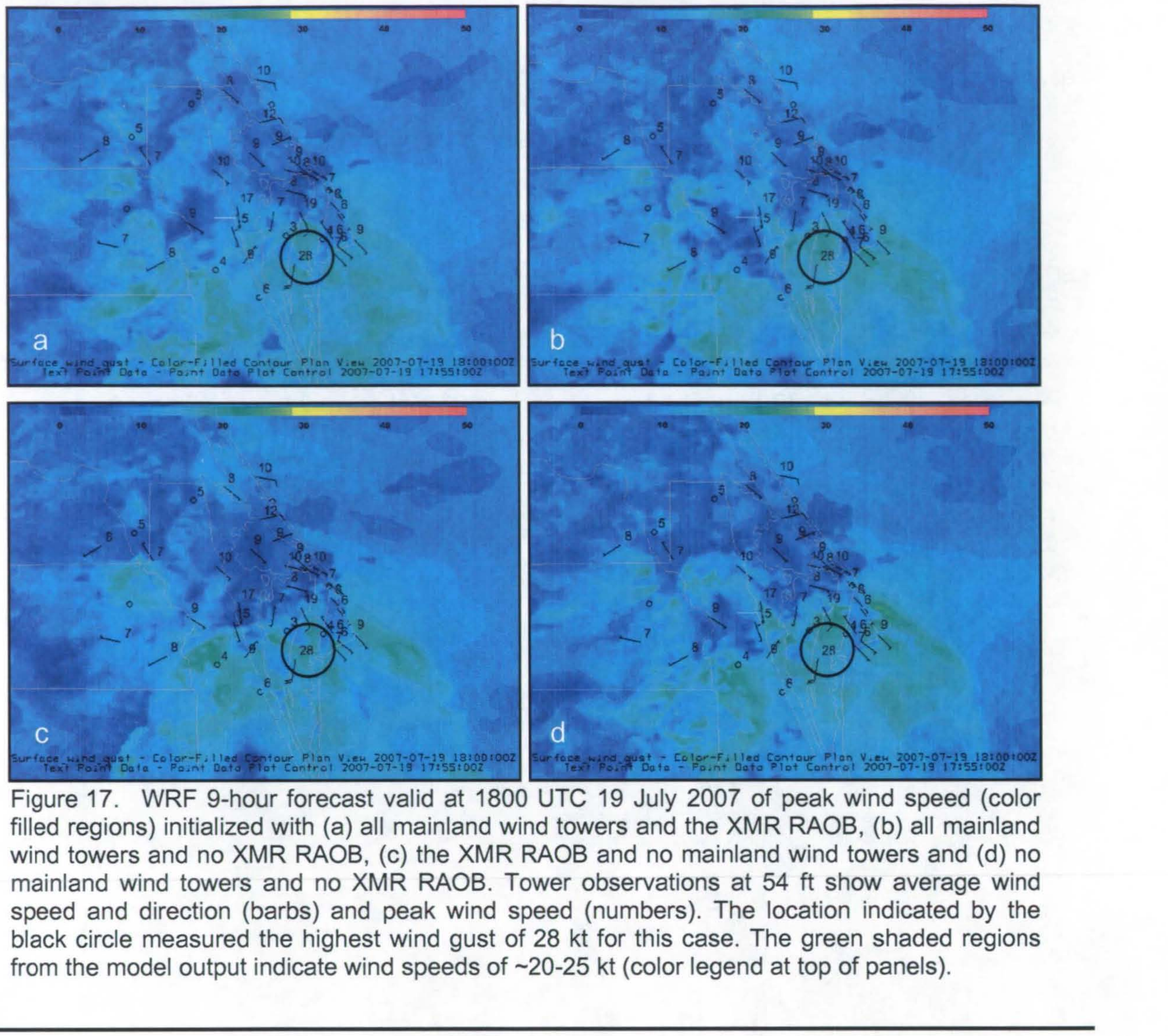

Figure 17. WRF 9-hour forecast valid at 1800 UTC 19 July 2007 of peak wind speed (color filled regions) initialized with (a) all mainland wind towers and the XMR RAOB, (b) all mainland wind towers and no XMR RAOB, (c) the XMR RAOB and no mainland wind towers and (d) no mainland wind towers and no XMR RAOB. Tower observations at 54 ft show average wind speed and direction (barbs) and peak wind speed (numbers). The location indicated by the black circle measured the highest wind gust of 28 kt for this case. The green shaded regions from the model output indicate wind speeds of ~20-25 kt (color legend at top of panels).

Radar Scan Strategies for the PAFB WSR-74C Replacement (Dr. Short)

The 45 WS is planning to replace the Weather Surveillance Radar, Model 74C (WSR-74C) at Patrick Air Force Base (PAFB) with a Doppler, Dual Polarization radar, the RadTec 43/250. This new radar will be located 20 n mi northwest of PAFB. A new scan strategy is needed to take advantage of the new radar's advanced capabilities for detecting severe weather phenomena associated with convection within the 45 WS area of responsibility, while providing high vertical resolution data over the KSC and CCAFS launch pads. Rapid updates of 3 min or less are required for evaluating LLCC and monitoring the growth and electrification of convective clouds. Radar products generated by the new data processing system will be used by forecasters of the 45 WS, SMG and NWS MLB to provide weather warnings and watches for convective wind events such as downbursts and mesoscale vortices which can spawn tornadoes. The new radar will also provide capabilities to detect cloud electrification, improving the timeliness of lightning advisories, while maintaining the capability for evaluation of LLCC. The AMU will evaluate the capabilities of the new weather radar and develop several scan strategies customized for the operational needs of the 45 WS. The AMU will also develop a plan for evaluating the scan strategies in the period prior to operational acceptance, planned for November 2008. The 45 WS will use the results of the evaluation to choose one or more of the scan strategies developed by the AMU.

Volume Scan Timing

The RadTec 43/250 radar antenna can be used operationally with an antenna rotation rate of 6 revolutions per minute (RPM), resulting in a 360° sweep completed in 10 seconds. To calculate the time to complete a volume scan, one must take into account the number of elevation angles and a 2.5 second interval required for the antenna to stabilize when changing elevation angles. Figure 18 illustrates the number of elevation angles that can be scanned in three minutes with these characteristics. The first 12 scans are completed in 2.5 minutes, and another 12.5 seconds are required to complete the 13th scan. Experience with the WSR-74C has shown that at least 12 elevation angles are needed to provide the required vertical resolution. In addition, the 45 WS requirement for updating the volume scan is within 2.5 minutes. However, the 45 WS has indicated that having 13 elevation angles to improve the vertical resolution is an acceptable trade-off for the increase in volume scan time beyond 2.5 minutes.

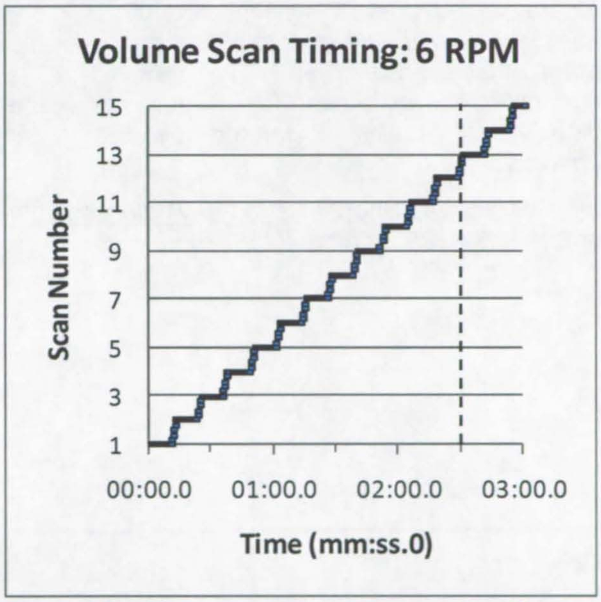

Figure 18. Time versus scan number for an antenna rotation rate of 6 RPM and a stabilization time of 2.5 seconds. The dashed vertical line denotes 2.5 minutes.

An interleaved scan is used to reduce wear on the mechanical systems driving the antenna. For numbered elevation angles increasing from low to high, the odd numbered ones are scanned first as the elevation increases, and then the even numbered ones are scanned as the elevation decreases. Figure 19 illustrates an interleaved scan with 13 elevation angles.

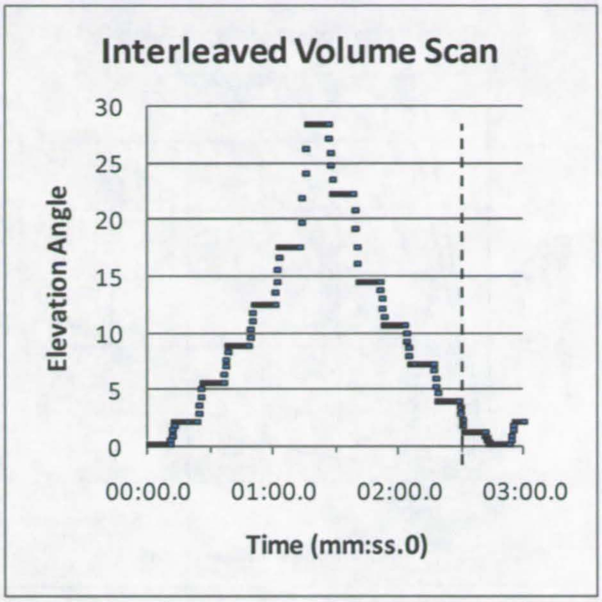

Figure 19. Time versus elevation angle for an interleaved volume scan of 13 elevation angles, assuming an antenna rotation rate of 6 RPM and stabilization time of 2.5 seconds. The dashed vertical line denotes 2.5 minutes. This volume scan completes in 2 minutes 42.5 seconds.

Range Versus Height Coverage

Mr. Roeder (45 WS) presented the possibility of a single scan strategy that could satisfy requirements for vertical coverage and LLCC evaluation during both warm and cool seasons. Dr. Short made the necessary adjustments to the original 45 WS scan strategy reported in the previous AMU Quarterly Report (FY 07, Q4). The resulting scan strategy is based on the time sequence of elevation angles shown in Figure 19, producing a beam coverage pattern that minimizes vertical gaps within 5 n mi of the launch complexes on KSC and CCAFS, which are approximately 23 n mi from the radar.

Figure 20 shows a range-height cross section for these elevation angles. The critical altitude range for evaluating LLCC is from about 7,000 to 27,000 ft. The requirement for vertical gaps is 2250 ft or less, because of the thick cloud rule that prohibits launch/landing trajectories through clouds having a thickness of 4500 ft or more, with any part of the cloud located between the 0°C and -20°C isotherms. This design ensures that at least two radar beams will sample a thick cloud over the launch complexes, if it has a thickness of 4500 ft or more. The radar beam is shaded to indicate its beam width of 0.95 degrees.

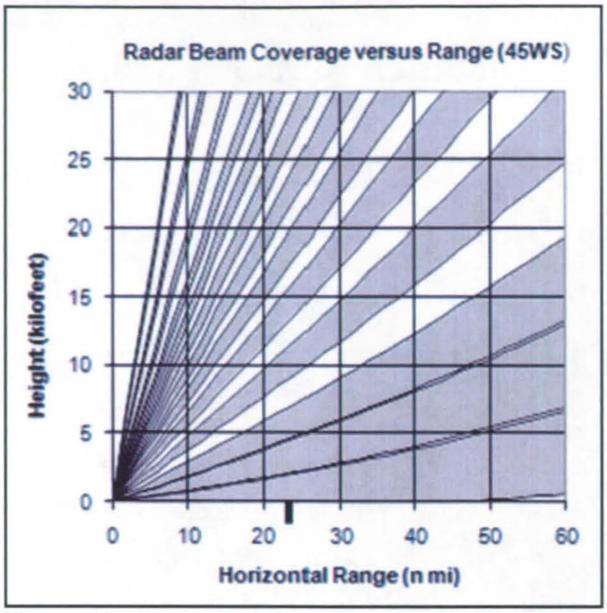

Figure 20. Range-height cross section of beam coverage for the elevation angles in Figure 19. The dark rectangle marks the range from the radar to the launch complexes on KSC and CCAFS.

Dr. Short developed another possible scan strategy by adding a 13th elevation angle to the AMU-designed WSR-74C scan strategy (Short 2000), lowering the lowest elevation angle to 0.2° and adjusting the higher elevation angles appropriately. Figure 21 shows a range-height cross section of beam coverage produced by the modified AMU design, resulting in vertical gaps independent of range out to a distance of 50 n mi and above an altitude of 7,000 ft. The average vertical gap produced by the beam pattern shown in Figure 21 is about 60% larger over the launch complexes than that produced by the beam pattern shown in Figure 20.

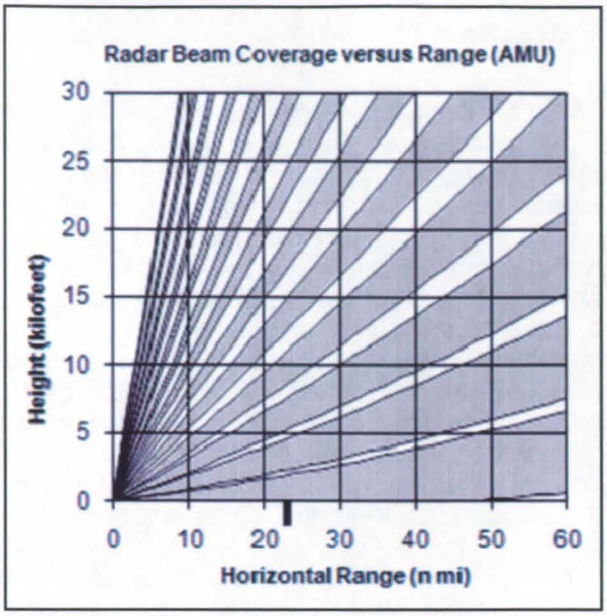

Figure 21. As in Figure 20, but for an AMU scan strategy that produces vertical gaps that are independent of range, for a given altitude.

The advantage of the scan strategy in Figure 21 is that it would produce a more homogeneous spatial sample of raw data over the radar surveillance area. The raw data is automatically smoothed for display, and the display is visually interpreted by the radar operator.

Contact Dr. Short at short.dave@ensco.com or 321-853-8105 for more information.

AMU CHIEF'S TECHNICAL ACTIVITIES (Dr. Merceret)

Dr. Merceret began work on an analysis of the probability distribution of gust factors in tropical storms and hurricanes land-falling near Cape Canaveral. The work, suggested by Shuttle Launch Weather Officer (LWO) Kathy Winters (45 WS), will provide objective guidance about the statistical properties of these high wind gust factors and their vertical and horizontal variations. He is using data from the KSC/CCAFS wind towers during hurricanes Frances and Jeanne (both in 2004) for the analysis.

AMU OPERATIONS

IT Communications

Dr. Bauman continued to work on switching the AMU from the ENSCO to the NASA communications network in the Morrell Operations Center (MOC, formerly Range Operations Control Center [ROCC]) by preparing a requirements statement for the Air Force. This statement was approved by Dr. Merceret and Mr. Roeder and entered into the Air Force tracking system. He also provided network information to KSC network personnel so they could generate a requirements statement for the work on KSC.

Dr. Bauman was notified that the KSC Weather Office requested the Shuttle LWO, Ms. Winters, be connected to the KSC network at her desk in the MOC. Therefore, Dr. Bauman scheduled a meeting to be held in January 2008 with KSC and 45 SW networking personnel to discuss combining efforts in switching the AMU from the ENSCO to the NASA communications network and adding the NASA capability for Ms. Winters.

Launch Support

Dr. Short supported the Atlas V launch of the Wideband Global SATCOM spacecraft, Dr. Watson supported the Delta II GPS launch, and Mr. Barrett supported the launch of STS-120 (Discovery). Dr. Merceret also supported all three operations. Dr. Merceret and Ms. Lambert supported the Delta-IV Heavy launch on 10 November. Drs. Bauman and Merceret supported the Atlas V NRO launch on 10 December and the Delta II GPS launch on 20 December.

Conferences and Meetings

AMU team members presented three papers at the 32nd NWA Annual Meeting in Reno, NV in October as follows:

- Mr. Barrett presented a poster titled "Creating Interactive Graphical Overlays in the Advanced Weather Interactive Processing System Using Shapefiles and DGM Files".
- Ms. Lambert presented a poster describing the results of Objective Lightning Probability Phase II task.
- Dr. Bauman gave an oral presentation titled "Flow Regime Based Climatologies of Lightning Probabilities for Spaceports and Airports".

AMU team members completed manuscripts for upcoming conferences at the 88th Annual Meeting of the AMS, 20-24 January 2008 in New Orleans, LA as follows:

- Ms. Lambert completed the manuscript titled "Developing a Peak Wind Forecasting Tool for Kennedy Space Center and Cape Canaveral Air Force Station" for the 19th Conference on Probability and Statistics;
- Mr. Barrett completed the manuscripts titled "Forecasting Cool Season Daily Peak Winds at Kennedy Space Center and Cape Canaveral Air Force Station" and "Development and Testing of the VAHIRR Product", both for the 13th Conference on Aviation, Range and Aerospace Meteorology; and
- Dr. Bauman completed the manuscript titled "Flow Regime Based Climatologies of Lightning Probabilities for Spaceports and Airports" for the Third Conference on Meteorological Applications of Lightning Data.

Ms. Lambert prepared an abstract titled "Update to the Lightning Probability Forecast Equations at Kennedy Space Center/Cape Canaveral Air Force Station, Florida" for the 2nd International Lightning Meteorology Conference (ILMC), 24 - 25 April 2008 in Tucson, AZ.

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List of Acronyms

30 SW	30th Space Wing
30 WS	30th Weather Squadron
45 RMS	45th Range Management Squadron
45 OG	45th Operations Group
45 SW	45th Space Wing
45 SW/SE	45th Space Wing/Range Safety
45 WS	45th Weather Squadron
ABFM	Airborne Field Mill Program
AFSPC	Air Force Space Command
AFWA	Air Force Weather Agency
AMS	American Meteorological Society
AMU	Applied Meteorology Unit
ARW	Advanced Research WRF
AWIPS	Advanced Weather Interactive Processing System
CCAFS	Cape Canaveral Air Force Station
CDF	Cumulative Distribution Function
CSR	Computer Sciences Raytheon
ESRL	Earth System Research Laboratory
EST	Eastern Standard Time
FR	Flight Rules
FSU	Florida State University
FY	Fiscal Year
GEMPAK	General Meteorological Package
GrADS	Grid Analysis and Display System
GSD	Global Systems Division
GUI	Graphical User Interface
IDV	Integrated Data Viewer
JAX	Jacksonville, FL 3-letter identifier
JSC	Johnson Space Center
KSC	Kennedy Space Center
LAPS	Local Analysis and Prediction System
LCC	Launch Commit Criteria
LLCC	Lightning LCC
LWO	Launch Weather Officer
MFL	Miami, FL 3-letter identifier
MLB	Melbourne, FL 3-letter identifier
MSFC	Marshall Space Flight Center
MSPD	Mean 5-minute Wind Speed
NCAR	National Center for Atmospheric Research
NetCDF	Network Common Data Form
NOAA	National Oceanic and Atmospheric Administration
NSHARP	National Skew-T Hodograph analysis and Research Program
NSSL	National Severe Storms Laboratory
NWS	National Weather Service
NWS MLB	NWS in Melbourne, FL
ORPG	Open Radar Product Generator
PAFB	Patrick Air Force Base, FL
QC	Quality Control
RAOB	Rawinsonde Observation
RPM	Rotations Per Minute
SLF	Shuttle Landing Facility
SMC	Space and Missile Center
SMG	Spaceflight Meteorology Group
SPoRT	Short-term Prediction Research and Transition
TBW	Tampa, FL 3-letter identifier
USAF	United States Air Force
UTC	Universal Coordinated Time
VAHIRR	Volume Averaged Height Integrated Radar Reflectivity
WRF	Weather Research and Forecasting Model
WSR-74C	Weather Surveillance Radar Model 74C
WSR-88D	Weather Surveillance Radar 1988 Doppler
XMR	CCAFS 3-letter identifier

Appendix A

AMU Project Schedule 31 January 2008				
AMU Projects	Milestones	Scheduled Begin Date	Scheduled End Date (*New End Date*)	Notes/Status
Peak Wind Tool for User LCC Phase II	Collect and QC wind tower data for specified LCC towers, input to S-PLUS for analysis	Jul 07	Sep 07 (*Nov 07*)	Delayed due to need for manual QC
	Stratify mean and peak winds by hour and direction, calculate statistics	Sep 07	Oct 07 (*Nov 07*)	Delayed as above
	Stratify peak speed by month and mean speed, determine parametric distribution for peak	Oct 07	Nov 07	Completed
	Create distributions for peak winds 2, 4, 8, and 12 hours	Nov 07	Dec 07 (*Feb 08*)	Delayed due to computational intensive script
	Develop a GUI that shows climatologies, probabilities of exceeding peak	Dec 07	Feb 08	On Schedule
	Final report	Feb 08	Apr 08	On Schedule
Peak Wind Tool for General Forecasting	Data collection: wind towers, XMR 100-ft soundings, 915-MHz profilers	Sep 06	Oct 06 (*Feb 07*)	Completed Delayed to obtain 915-MHz profiler data
	Software development: wind tower data QC, sounding inversion detection, 915 MHz total power display	Sep 06	Dec 06 (*Mar 07*)	Completed Delayed to modify the AMU wind tower QC software
	Data analysis	Dec 06	Feb 07 (*Jun 07*)	Completed Delayed to add recent data sets
	Interim evaluation	Feb 07	Mar 07	Completed
	Forecast tool development, if approved	Mar 07	May 07 (*Jan 08*)	Delayed due to work on VAHIRR
	Final report	Jun 07	Jul 07 (*Feb 08*)	Delayed as above

AMU Project Schedule 31 January 2008				
AMU Projects	Milestones	Scheduled Begin Date	Scheduled End Date (*New End Date*)	Notes/Status
Situational Lightning Climatologies for Central Florida, Phase III	Customize AWIPS so that the composite soundings can be viewed in the D2D application	Jul 07	Sep 07 (*Oct 07*)	Delayed due to work on VAHIRR task
	Develop application to create NetCDF files from NSHARP upper-air sounding files	Nov 07	Dec 07 (*Jan 08*)	Delayed due to work on VAHIRR
	Add NetCDF files to AWIPS	Dec 07	Feb 08	On Schedule
	Final Report	Jan 08	Feb 08	On Schedule
Volume-Averaged Height Integrated Radar Reflectivity (VAHIRR)	Acquisition and setup of development system and preparation for Technical Advisory Committee meeting	Mar 05	Apr 05	Completed
	Software Recommendation and Enhancement Committee meeting preparation	Apr 05	Jun 05	Completed
	VAHIRR algorithm development	May 05	Oct 05 (*Jul 06*)	Completed – Delayed due to new code development made necessary by final product requirements
	ORPG documentation updates	Jun 05	Oct 05 (*Sep 06*)	Completed Delayed as above
	Configure ORPG and AWIPS system in the AMU for live data testing.	Oct 05	Jan 06 (*Apr 07*)	Completed Delayed as above
	Conduct Acceptance Test Procedures	May 07	Aug 07 (*Jan 08*)	Completed – Failed, testing to find reason for failure
	Preparation of products for delivery and memorandum	Oct 05	Jan 06 (*Feb 08*)	Delayed as above

AMU Project Schedule 31 January 2008				
AMU Projects	Milestones	Scheduled Begin Date	Scheduled End Date (*New End Date*)	Notes/Status
Impact of Local Sensors	Identify candidate warm and cool season days and archive data	Jul 07	Jan 08	On Schedule
	Configure LAPS to ingest all data and write scripts to ingest all Eastern Range wind tower and RAOB data	Aug 07	Sep 07	Completed
	Run LAPS-ARW "with and without" tests for all warm and cool season candidate days	Sep 07	Jan 08	On Schedule
	Validate and compare forecast results	Sep 07	May 08	On Schedule
	Final Report	May 08	Jun 08	On Schedule
Radar Scan Strategies for PAFB WSR-74C Replacement	Development and analysis of scan strategies based on vendor suggestions, radar characteristics and 45 WS requirements	Aug 07	Nov 08	Completed
	Develop plan for evaluating scan strategies	Dec 08	Jan 08	On Schedule
	Develop training on implementation of new scan strategy into the radar's configuration files	Feb 08	Mar 08	On Schedule
	Final Report	Mar 08	May 08	On Schedule

NOTICE

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This report summarizes the Applied Meteorology Unit (AMU) activities for the first quarter of Fiscal Year 2008 (October - December 2008).

15. SUBJECT TERMS
Applied Meteorology Unit, Quarterly Report, Weather, Forecasting

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